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Full Length Research

Physico- Chemical and Microbial Analysis of Selected Borehole Water in Obio/Akpor Local Government Rivers State, Nigeria

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The study examined borehole water quality in selected communities in Obio-Akpor LGA, Rivers State, Nigeria. Study adopted experimental research method. Primary and secondary data sources were used. Global Positioning System (GPS) was used to track the borehole positions for each community. The random sample technique was used to select 9 wards and nine communities for water sampling. Nine boreholes purposively were sampled in the nine communities for laboratory analyses on the physical, chemical and microbial parameters of the water samples. Physico-chemical parameters analyzed were: pH, temperature, chloride, acidity, hardness, colour, odour, total dissolved solids (TDS), total suspended solids (TSS) and oil and grease. The microbial parameters were E coli and Salmonella. Descriptive and inferential statistics were used for the study and statistical analyses were performed using SPSS version 21.0. Results showed that mean values of physical parameters were; pH (6.5), temperature (25.9 ^{0}C), chloride (62.8 mg/l), acidity (60.6 mg/l), hardness (20.87 mg/l), colourless, odourless, (TDS) (54.1 ppm), (TSS) (57.5 mg/l) and oil and grease (563 mg/l. Microbial parameters were; E coli (0 cfu/100 ml) and Salmonella (0 cfu/100 ml) were not found. Hypothesis test showed a statistical significant difference between the borehole water quality as indicated by Chloride, Acidity, Hardness, TDS, TSS and Oil/grease and WHO standard for drinking water in the study area. Findings also revealed that values obtained for physico-chemical were lower than NESREA standards and WHO acceptable limits except for higher values of TSS recorded at Choba and Rumuola sample stations. Oil and grease were also found to be higher in content, higher than WHO and NESREA standards in these two areas, this was an indication of pollution. The study recommends that anthropogenic activities should be monitored in the area both on surface and ground water to reduce groundwater seepage and pollution in the study area.

Key words: Physico-Chemical, Microbial, Analysis, Borehole Water, Obio/Akpor.

INTRODUCTION

Groundwater is a major source of drinking water and other domestic activities globally and for people living in Obio/Akpor. Its availability, quality and usage to the people of the local government must however be of acceptable standards to prevent adverse effects on human health and aid the attainment of developmental goals (Adeleye,et al., 2003). Natural phenomena such as salt water intrusion into fresh water aquifers, weathering and leaching of chemical compounds into aquifers, and anthropogenic activities such as improper waste management methods, improper poor storage and delivery of water to homes, can alter the quality and availability of ground water for usage (Palamuleni and Akoth, 2015). Water moving through underground rocks and soils may pick up natural contaminants, even with no human activity or pollution in the area (Beltaos et al., 2006). The concentration of population and business activities in the study area is accompanied by rapid increase in the volume of waste generated from production and consumption activities which may cause serious pollution of underground water (Adekunle, et al., 2007). Consequently, as a result of the huge water storage and the inability of the Rivers State Water Board to provide enough potable water, there has been the proliferation of bore holes mostly on commercial basis to serve the ever-increasing population in Obio-Akpor local government. Another major problem with urbanized areas like Obio-Akpor, was not just the provision of adequate water supply but the maintenance of the water system, that is its potability for use by the residents (Ezekwe, 2012). Most residents did not understand that unclean water was harmful to health and livability of the people. Furthermore, due to the level of industrial activities in the study area, there has been an increase in the discharge of chemical pollutants and waste which percolates and infiltrate into the aquifer which can contaminates the water table (Wariso, 2000). Pollution of waters both surface and underground with waste effluents arising from various sources like industrial effluents, agricultural effluents, domestic and household wastes has become a serious problem in Nigeria, as population increases has put pressure on land and water, thereby causing environmental Pollution. It is against this backdrop that this study examined the Physico- Chemical and Microbial analysis of some selected Boreholes in Obio/Akpor local government Rivers State.

Aim and Objectives

The aim of the study was to analyze some borehole water to ascertain their quality and portability in selected areas in Obio-Akpor Local Government, Rivers State, Nigeria. To achieve the aim, the following objectives were suggested as follows to;

(i) Determine the physico-chemical and microbiological constituents of borehole water in the study area.
(ii) Determine the potability of the borehole water in the study area for residents' consumption
(iii) Ascertain if the quality of the borehole water in the study area is in consonance with the National Environmental Standards and Regulations Enforcement Agency (NESREA) and World Health Organization (WHO) water quality standards.

Hypothesis Statement

Ho: There is no statistically significant difference between the Borehole water quality and WHO standard for drinking water in the study area.

METHOD OF STUDY

Present study adopted the experimental research design. The sources of data include; primary and secondary sources. The primary data involved the collection of borehole water samples from the study area. Standard methods and procedures were used for the water samples collected. The water samples were analyzed for physico-chemical and microbial properties. The secondary data was derived from journals, textbooks and the internet resources.

Sampling Frame and Sampling Techniques

Obio-Akpor Local Government is made up of 89 communities as delineated by National Population Commission (1991). Furthermore INEC (2009) delineated Obio/Akpor into 17 wards. A listing of wards was done and a random sampling technique applied to selected areas to collect sample. At the end, 9 wards were selected and a random sample adopted to select communities to collect the samples. The list of communities as shown in Table 1 was randomly selected for equal representation. In

Table 1. List of Communities Selected from Sampled Wards.

Wards	Communities	Selected community
Ward1	Rumuewhara,Eliozu, Rumunduru and Elimgbu	Eliozu
Ward 6	Woji, Rumurolu, Rumuibekwe Rumuogba and Oginigba	Woji
Ward 7	R umookoro,Rumuagholu, EliKparawo,Eliogbolo, RuKpakwulusi, Bori-camp and FGC P.H	Rumuokoro
Ward10	Rumueme, Oroagbolu, Eligbam,Oroazi,Rumuchinda,Mgbosimini and Oroakwor.	Oroazi
Ward 12	Rumuigbo,Rumuomoi,Nkpolu, Mgbesilaru and Rumuorosi.	Nkpolu
Ward 13	Choba,Rumuosi,Rumuekeni, Alakahia	Choba
Ward15	Rumuoadaolu,Rumuola,Rumuokwuta,Mgbuoba	Rumuola
Ward 16	Ozuoba,Ogbogoro,Rumuokwachi and Rumukparali	Ozuoba
Ward17	Rumuolumeni,Mgbosimini, Nkpor-rumuolumeni, Mgbosimini, Minikit and Mguakara	Rumuolumeni

each ward, one community was selected for water sample. The compound where boreholes samples were sampled was purposively selected for convenience and representative. On the whole about (9) water borehole samples were collected from the sampled communities.

Materials for Sampling and Analysis

- Plastic bottles
- Ice packed cooler
- Masking tape
- Marker
- Field note (to record time sample was collected and chain of custody of samples)

Borehole water was collected in plastic bottles which were rinsed with the borehole water before collection. The samples collected were properly labeled for each location and chain of custody of samples noted. Laboratory Analysis was carried out for, **Physical parameters;** temp, colour, odour, oil and grease, TDS, TSS and **Chemical;** PH, CL, hardness/acidity and Microbiological**;** E -Coli and Salmonella. The Figure 1 shows the coordinates and sample point from the nine communities in Obio/Akpor Local Government were borehole waters samples were collected.

Impact of Water Potability on Health, Biophysical and Scio-economics and Environment

When the quality of water consumed by the populace is not safe, it could lead to public health break down from water borne diseases (Table 2) with the attendant economic and social adverse effects (USEPA 1994). Protecting groundwater supplies from contaminants reduces the extent of treatment needed to protect public health. According to Sangodoyin (1993), bacteria can thrive in contaminated water as they are supported by chemical constituents of the contaminants particularly from organic wastes. Biodegradation of organic wastes by indigenous subsurface bacteria is assumed to be affected by physical, chemical and biological factors such as temperature, concentration of inorganic nutrients, hydrogen ion activity, levels of dissolved oxygen and the presence of other toxic substances (UNICEF, 2010 and WHO, 2010).

DATA ANALYSIS

The study utilized the descriptive and inferential statistics for data presentation and analysis. Descriptive analyses were used to present information obtained on the physico-chemical parameters, as well as comparison with WHO standards for drinking water quality. Data analysis was presented using tables and graphs. The physical and chemical properties of water samples were explained using the mean values. The one sample T-test analysis was used to test the hypothesis stated for the study. The one sample T-

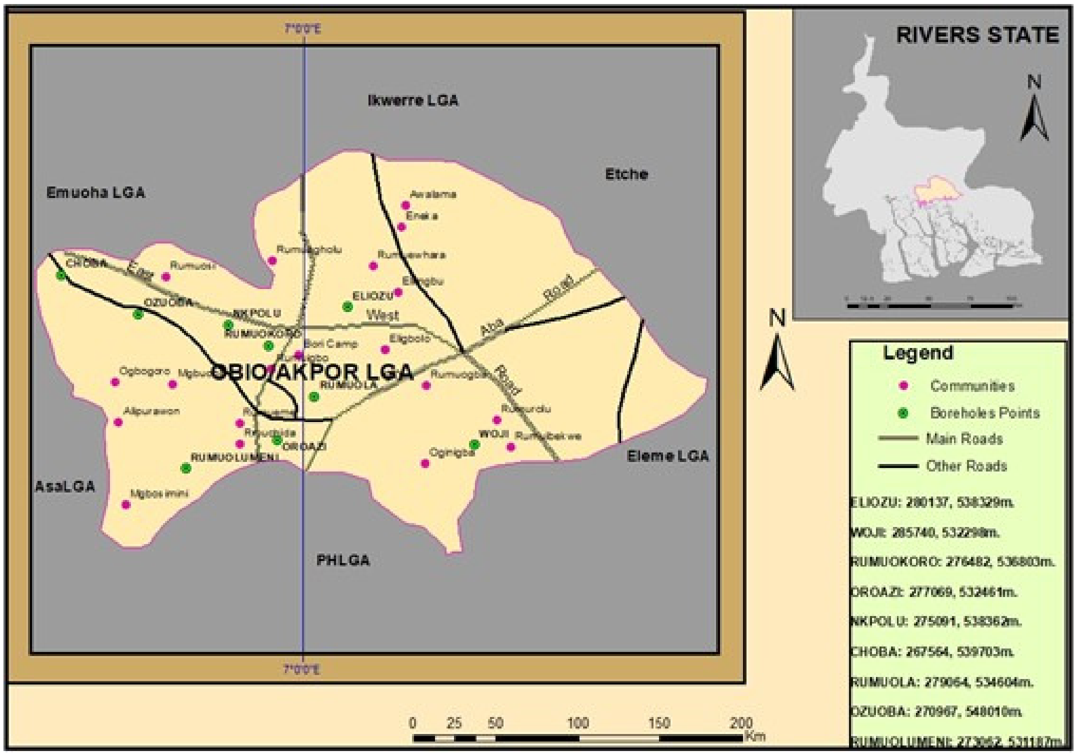

Figure 1. Obio/Akpor Local Government showing communities where borehole water Samples were collected. Source (Cartography Laboratory Department, 2019)

test was employed because it showed the level of variation in paired sample of mean values for each physico-chemical parameter with WHO standard for drinking water. All statistical analyses were performed using the Statistical Package for Social Scientist (SPSS) version 21.0.

RESULTS

Physical and Chemical Properties of Groundwater in the Study Area

The information obtained for the physico-chemical properties of groundwater in sampled borehole facilities was displayed on Table 3. The analysis shows that temperature ranged between 24 ^{0}C and 28 ^{0}C while the mean value was 25.9 ^{0}C. Rumuola recorded the highest mean temperature of 28 ^{0}C. The pH values ranged between 5.51 and 7.36 and recorded mean value of 6.5. The highest pH level of 7.36 was recorded at Ozuoba. The means of pH concentration was slightly acidic in the study area. The concentration of chloride (mg/l) ranged from 4.33 (mg/l) to 428.2 (mg/l) with mean concentration value of 62.8 (mg/l). The highest mean value of chloride was recorded at Rumuokoro sampling station. The level of acidity (mg/l) showed range of values between 6.3 (mg/l) and 133.33 (mg/l) and a mean concentration value of 60.6 (mg/l). High acid in water can lead to elevated toxic metals in water which gives water a sour taste. The highest mean concentration was recorded at Rumuolumeni sampling station which was more acidic than other sampling stations. The water hardness recorded range values between 4.8 (mg/l) and 42.68 (mg/l) with mean value of 20.87 (mg/l) in the study area. The level of hardness in water indicates the sum of calcium and magnesium concentration in water usually between 40-80 ppm. The highest water hardness was recorded at Rumuokoro sampling stations. The colour of water sampled revealed that all water samples were colourless except the water samples at Rumuokoro and Choba which showed light yellow colour. The odour of sampled water also revealed odourless water except at Rumuokoro and Choba which were objectionable and stale. Total dissolved solids (TDS) showed range values

Table 2. Water Borne Diseases.

Water Borne Disease	Causative Organism	Source of Organism in Water	Symptom
Gastro enteritis	Rotavirus	Human Faeces, Sewer	Acute diarrhea or vomiting
	Salmonella (bacterium)	Animal or human faeces, Sewer	Acute diarrhea or vomiting
	Entheropathogenic E. Coli	Human Faeces, Sewer	Acute diarrhea or vomiting
Typhoid	Salmonella typhosa. (bacterium)	Human Faeces, Sewer	Inflamed intestine, enlarged spleen, high temperature, - sometimes fatal.
Dysentery	Shigella sp. (bacterium)	Human Faeces, shell fish grown in polluted water	Diarrhea – rarely fatal.
Cholera	Vibrio cholera	Human Faeces, Sewer	Diarrhea – rarely Fatal
Infectious hepatitis	Hepatitis A (Virus)	Human Faeces, Sewer	Vomiting, severe diarrhea, rapid dehydration, mineral loss, - high mortality.
Amoebic dysentery	Entamoeba histolitica	Human Faeces, Sewer.	Mild diarrhea, chronic dysentery.
Giardiasis	Giardia lambilia (protozoa)	Animal or human faeces	Diarrhea, cramps, nausea, and general weakness. – Not fatal, lasts 1 week to 30 weeks.
Cryptosporidiosis	Cryptosporidium (protozoan)	Animal or human faeces.	Diarrhea, stomach pain- lasts an average of 5 days.

Source: United States Environmental Protection Agency (1994) – Environmental Pollution Control Alternatives; Drinking Water Treatment for Small Communities.

between 21.3 ppm and 80 ppm with mean value of 54.1 ppm. The highest concentration of TDS was recorded at Rumuolumeni sampling station. For total suspended solids (TSS), the range of mean values was between 10.33 mg/l and 160.1 mg/l while the mean value from all sampling stations was 57.5 mg/l. The highest TSS (mg/l) concentration was recorded at Choba. High TSS (mg/l) has effect, which shows the presence of silt, decaying plants and animal matter. The level of concentration for oil/grease constituents in water revealed that mean concentration among sampling stations of values ranging between 56.6 mg/l and 1066.66 mg/l. The mean value was 563 mg/l and the highest was recorded in Rumuolumeni sampling stations. Oil/grease was an indication of pollution, an indication of contaminants items being flushed down into the water.

Comparison of Physico-Chemical Parameters with NESREA and WHO Standards

Table 4 presents the comparison of the values obtained for each physical and chemical parameter of groundwater quality with the NESREA and WHO standards of quality drinking water, that is, NESREA

Table 3. Physico-Chemical Parameters of Ground Water Quality.

Sample Stations	Temp. (⁰C)	pH	Cl (mg/l)	Acidity (mg/l)	H	Colour (TCU)	Odour	TDS (ppm)	TSS (mg/l)	Oil/ Grease (mg/l)
1(Eliozu)	28	6.1	27.63	102.36	26.9	Colorless	Odorless	40.6	40.3	300.3
2(Woji)	27.3	5.51	15.2	10.9	20	Colorless	Odorless	65	10.33	327.1
3(Rumuokoro)	26.8	6.99	11.86	6.3	11.1	Colorless	Odorless	21.3	60	566.4
4(Oroazi)	27.8	7.36	4.33	10.33	4.8	Colorless	Odorless	60	61	750
5(NKpolu)	25.66	6.76	10.8	133.33	12.16	Colorless	Odorless	80	53.33	1066.66
6(Choba)	24	6.4	42.82	140	42.68	Light yellow	Objectionable	60	82.66	733.3
7 (Rumuola)	26.3	6.76	12.6	14.86	10.66	Colorless	Odorless	60	23.33	666.66
8 (Ozuoba)	24	7	23.33	12.33	24.4	Colorless	Odorless	60	26.66	56.6
9(Rumuolumeni)	23.66	5.6	30.86	115.2	35.13	Light yellow	Stale	40	160.1	600
Mean	**25.9**	**6.5**	**62.8**	**60.6**	**20.87**	**-**	**-**	**54.1**	**57.5**	**563**

Temp: Temperature; Cl–Chloride; H–Hardness; TDS-Total Dissolved Solids; TSS-Total Suspended Solids; Stations 1-9 (Rumuola, Nkpolu, Eliozu, Ozuoba, Rumuolumeni, Rumuokoro, Woji, Oroazi and Choba).

standards and WHO maximum acceptable limit. The results showed that the values for each physical and chemical parameter for each sampled borehole were all lower when compared with the NESREA and WHO standards of groundwater quality for drinking water. In other words, NESREA standards and WHO permissible limits had higher values than the obtained values of the groundwater physical and chemical parameters understudied in the sampled borehole sites in the study area. However, for TSS (mg/l) and Oil/grease (mg/l) the overall mean value of TSS of 57.5 mg/l was lower than permissible standards but was higher (160.1 mg/l) at sampling station 9 (Choba). The higher values of TSS shows that more particles of silt, decaying plants and animal matter were found in the water samples collected for the study. The oil/grease (mg/l) showed higher mean concentration in all sampling stations except for Oroazi sampling station which measured 56.6 mg/l of oil/grease which is within permissible limit. The presence of excess oil and grease was an indication of pollution which means more unsuitable items are found in the underground water in the study area. To this effect, the groundwater found in the study area would have passed the potability test except for high constituents of oil and grease which were found to be higher than WHO and NESREA standards. However, the slight variation between NESREA (500 mg/l) standard and WHO (<1000 mg/l) for total dissolved solids (TDS) was as a result of what is obtainable in a country, which are usually based on taste (NESREA, 2011).

Hypothesis Testing Hypothesis

H_0: There is no statistical significant difference between the borehole water quality and WHO standard for drinking water in the study area.

H_1: There is statistical significant difference between the borehole water quality and WHO standard for drinking water in the study area.

Table 5 presents the results computed for the stated hypothesis using the One Sample T-test. The distribution showed that the level of significance 0.05, that 0.798 and 0.992 for temperature (⁰C) and pH were higher which means the null hypothesis (H_o) was accepted for these parameters. Thus, there is no statistical significant difference between the borehole water quality as indicated by Temperature and pH and WHO standard. However, on the other hand, the level of significance of 0.05,

Table 4. Physico-Chemical Properties of Groundwater with NESREA and WHO Standards.

Bore hole Sample Station	Temp. (^{0}C)	pH	Cl (mg/l)	Acidity (mg/l)	H	Colour (TCU)	Odour	TDS (ppm)	TSS (mg/l)	Oil/ Grease (mg/l)
1	28	6.1	27.63	102.36	26.9	Colorless	Odorless	40.6	40.3	300.3
2	27.3	5.51	15.2	10.9	20	Colorless	Odorless	65	10.33	327.1
3	26.8	6.99	11.86	6.3	11.1	Colorless	Odorless	21.3	60	566.4
4	27.8	7.36	4.33	10.33	4.8	Colorless	Odorless	60	61	750
5	25.66	6.76	10.8	133.33	12.16	Colorless	Odorless	80	53.33	1066.66
6	24	6.4	42.82	140	42.68	Light yellow	Objectionable	60	82.66	733.3
7	26.3	6.76	12.6	14.86	10.66	Colorless	Odorless	60	23.33	666.66
8	24	7	23.33	12.33	24.4	Colorless	Odorless	60	26.66	56.6
9	23.66	5.6	30.86	115.2	35.13	Light yellow	Stale	40	160.1	600
Mean	**25.9**	**6.5**	**62.8**	**60.6**	**20.87**	**-**	**-**	**54.1**	**57.5**	**563**
WHO**	**Ambient**	**6.5-8.5**	**<250**	**300**	**300**	**15 TCU**	**-**	**<500**	**<100**	**100**
NESREA*	**Ambient**	**6.5**	**250**	**300**	**300**	**-**	**-**	**500**	**100**	**-**

* NESREA, 2011; **WHO, 2006

the other physic-chemical parameters were; 0.003, 0.000, 0.000, 0.000, 0.024, 0.01, and 0.000 lower in the water. This means that all were significant at degrees of freedom of 9. Thus, the null hypothesis (H_0) was rejected for all these (Chloride, Acidity, Hardness, TDS, TSS and Oil/grease) The alternative hypothesis (H_1) was accepted, which means that there is a statistical significant difference between the borehole water quality as indicated by Chloride, Acidity, Hardness, TDS, TSS and Oil/grease and WHO standard for drinking water in the study area.

Microbiological Analysis

Total coliform bacteria are known as "indicator organisms" meaning that their presence provides indication that other disease causing organisms may also be present in the water body. The total bacterial (E.Coli) count was 0 cfu/100 ml, and Samollena was 0cfu/100ml. Although information on the depth of the sampled boreholes was not available. There was no contamination of the sample water bore holes with Ecoli and Samollena.

DISCUSSION

Findings revealed slight acidic content in Ozuoba borehole facilities in the pH level, however, it was found to be within WHO (2006) and NESREA (2011) permissible limits for water quality. Similarly, the areas with lower mean values (especially Choba) show slightly acidic trend, and because the pH of water was generally influenced by the geology of the catchment area and buffering capacity of water, the low pH values reported for the samples may be due to the geology and elevation of the area and also high levels of free CO_2 which may consequently affect the bacteria counts. Conversely, the pH of water was very important because changes in pH values may affect the toxicity of poisonous substance in the water (WHO, 2006). The variation in pH among sampling stations may be due to the level of CO_2 content in respective water samples because pH level in water fluctuates daily because of photosynthesis and transpiration in water. Temperature (^{0}C) varied among sampling stations but was lowest at Choba sampling station. The ambient temperature limit for water quality was stated as a regulatory standard. However, the highest temperature level was experienced at Rumuola sample station. The hardness in water indicates the sum of calcium and magnesium salt contents. The hardness value ranges from 0-17.1 mg/L for soft water, 17.1-60 mg/L for slightly hard, 60-120 mg/L for moderately hard, 120-180 mg/L for hard, while above 180 mg/L indicates a very hard

Table 5. One sample T-test computed for Hypothesis.

Physico-Chemical/ Properties	One sample T-test						Remark
	T test	Df (n-1)	Significant At 0.05 alpha level	Mean Difference	95% Confidence Interval of the Difference		
					Lower	Upper	
Temp	-.264	8	0.798	-.14222	-1.3825	1.0981	NS
pH	-.010	8	0.992	-.00222	-.4978	.4933	NS
Chloride	-4.091	8	0.003	-187.24333	-292.7903	-81.6964	S
Acidity	-11.992	8	0.000	-239.37667	-285.4061	-193.3473	S
Hardness	-66.617	8	0.000	-279.14000	-288.8027	-269.4773	S
TDS	-77.462	8	0.000	-445.90000	-459.1742	-432.6258	S
TSS	-2.787	8	0.024	-42.14333	-77.0085	-7.2782	S
Oil	6.735	8	0.000	524.11333	344.6549	703.5718	S

* S – Significant; NS – Not Significant
* E coli and Salmonella were not computed because of 0 mean value obtained.

water. Findings revealed that the total hardness of all sampled borehole revealed mean value that fall within the slightly hard groundwater hardness. Thus, the collected groundwater samples were all within the standard limits of 300mg/L of $CaCO_3$ and 50 mg/L (Ca) and 80 mg/L (Mg). Therefore, findings revealed that total hardness values have been reported for similar studies carried out in Owerri and Nsukka by (Edema et al., 2001) and (Onweluzo and Akuagbazue , 2010) both in south east Nigeria. The borehole water samples were all soft water, since the hardness values fell within the stipulated range of 0-75 mg/L for soft water. Findings of the study also revealed that water samples were colourless and odourless except for samples taken at Rumuokoro and Choba which were light yellow. Colour or colourless water does not mean water was not safe for drinking, but it contains some immiscible particles which affect the colour of the water. Thus, more particles and solutes were found in water samples collected at Rumuokoro and Choba sampling stations. The concentration of TDS (mg/l) in sampled water showed higher mean values at Ozuoba, Rumuolumeni (highest), Rumuokoro, Woji and Oroazi (though were found to be within permissible limit), but this could be an indication of the taste of the water because of increased levels of TDS in water which could produce undesirable taste which affects potability. Therefore, the lesser the concentration of TDS (mg/l) in water samples the better the taste and water quality. TSS (mg/l) content in water was also found to fall within permissible limits but high content was discovered at Choba sampling stations which recorded a mean value of 160.1 mg/l (higher than WHO and NESREA standards). High TSS (mg/l) has effect on the concentration of silt, decayed plants remains and animal matter. Oil and grease content were found in high quantities in (Choba) because of its close proximity to the New Calabar River, whre oil and gas activities are carried out. The sample has higher oil and grease than WHO and NESREA standards for safe and quality drinking water. Oil and grease was an indication of pollution. The area was characterized with exploration and exploitation of crude oil which can pollute underground water resources in the within the area. Findings also revealed that all the physico-chemical parameters understudied were within the standard limits recommended by WHO except for oil and grease content which were found in high contents in sampled water in some sample points in the study area.

CONCLUSION

The study examined the physico-chemical properties of borehole water in Obio-Akpor local government. The study discovered that the mean

values of the sampled parameters were lower than WHO standard for drinking water quality except for high content of oil and grease found in most water samples which was an indication of the presence of pollution. Therefore, the study concludes that the groundwater quality of sampled boreholes in selected communities in Obio-Akpor was not potable and unsafe for human consumption. The study concludes that due to the high content in oil and grease recorded at all sampling stations except for Oroazi sample point, thereby creates the feeling of unsafe for drinking. The study, therefore, categorized the sampled borehole water to be less potable and unsafe for drinking. Thus, in order to promote good quality borehole water facilities in the study area, it was suggested as follows:

- Anthropogenic activities should be monitored both on surface and ground water to reduce groundwater seepage and pollution in the study area.
- Research on the entire community should be done especially the areas where their groundwater status has not been determined amidst current development in the study area in order to establish the extent of pollution.
- Activities tampering with the topography of the area should be discouraged especially digging of burrow pits for road construction as it will encourage overland surface run-off which will have several implications for underground water pollution in the study area.
- Proactive measures should be adopted by government in monitoring and the activities of Multinational oil companies and local manufacturers in order to promote sustainable environmental protection in the study area.

REFERENCES

Adekunle IM, Adetunji MT, Gbadebo AM and Banjoko OB (2007). Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. Int. J. Environ. Res. Publ. Health, 4(4):307-318.

Adeleye JA and Adebiyi AA (2003). Physicochemical and Microbiological Assessment of Okooba - A Nigerian Abattoir. J. Environ. Biol., 24, 309-313.

Beltaos S, Prowse TD and Carter T (2006). Ice regime of the lower Peace River and ice-jam flooding of the Peace-Athabasca Delta. Hydrological Processes, 20: 4009–4029.

Edema MO, Omemu AM and Fapetu OM (2001). Microbiology and Physicochemical Analysis of different sources of drinking water in Abeokuta Nigeria. Nig. J. Microbiol., 15(1): 57 – 61.

Ezekwe IC (2012). Assessing Regional Groundwater Quality and its Health Implications in the Lokpaukwu, Lekwesi and Ishiagu mining areas of Southeastern Nigeria using factor analysis. 67(4)

Geography and Environmental Management Department (2019). Cartography Laboratory, University of Port Harcourt, Nigeria.

Independent National Electoral Commission (2009). Nigeria Electoral Guide line.

National Environmental Standards and Regulations Enforcement Agency (NESREA, 2011) Standards for Drinking Water in Nigeria.

National Population Commission (1991). Nigeria Population Census Analysis, Vol.2. National Population Commission, Abuja.

Onweluzo JC and Akuagbazie CA (2010). Assessment of the quality of bottled and sachet water sold in Nsukka town. Agro science J. Tropical Agriculture, Food, Environment and Extension, 9(2): 104 – 110.

Palamuleni L and Akoth M (2015). Physico Chemical and Microbial analysis of selected borehole water in Mahikeng, South Africa. Journal of Environmental Research and Public, 2015 - mdpi.com.

Sangodoyin AY (1993). Considerations on Contamination of Groundwater by Waste Disposal Systems in Nigeria. Environmental Technology.14:957–964.

UNICEF (2010) and WHO (2010). Progress on Sanitation and Drinking-Water: Joint Monitoring Programme for Water Supply and Sanitation, Update.

United States Environmental Protection Agency (1994). – Environmental Pollution Control Alternatives; Drinking Water Treatment for Small Communities. The Natural Water Cycle. Pp 61-69

Wariso MC (2000). Assessment of borehole water in Diobu area of Port Harcourt Metropolis. Journal of Environment and Earth Science,Vol.4, No.23.

World Health Organization (WHO), (2006).Guidelines for drinking water quality, Vol.1, 3rd edition, WHO Press, Switzerland.